Ozone and aerosol information in ground-based zenith-sky ultra-violet radiance measurements

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Objectives:

- To assess the impact of tropospheric and stratospheric aerosols on C-pair zenith sky measurements used for Umkehr retrievals
- To examine the possibility of retrieving aerosol parameters from Brewer zenith-sky measurements at 326 nm
- To evaluate whether the information can be used to remove aerosol errors from the Umkehr measurement

Information in Brewer C-pair wavelength measurements:

- Zenith radiance measurements at 310 and 326 nm (C-pair) wavelengths as function of solar zenith angle
- For mid-latitude ozone profile (350 DU total ozone) C-pair N-values range from 70 units at 60-degrees SZA to 150 units at 85-degrees SZA
- Traditional Products:
  - Ozone profile
  - Total ozone
- Aerosols affect measurements, error has to be corrected

Tropospheric aerosols:

- Non-absorbing case:
  - -sulfate composition,
  - -optical depth=0.3
- Absorbing case :
  - -sulfate composition,
  - -single scattering albedo=0.9,
  - -optical depth=0.3,
  - -three size distributions (see Table 1)

Stratospheric aerosols:

- Non-absorbing case:
  - -sulfate composition,
  - -optical depth=0.1,
  - -single size distributions,
  - -four profiles (maximum aerosol load at 10, 15, 20, and 25 km)

Effect on C-pair wavelength:

- C-pair N-values are affected by tropospheric (Figure 1a) and stratospheric aerosols (Figure 1b). 1 N-value change is equal to –2.3 % change in radiance ratio.
- Normalized N-values (used to derive ozone profile) are not seriously affected by tropospheric aerosols, but the effect of stratospheric aerosols is significant (Figure 1c)
- The ozone profile is not affected by tropospheric aerosols
- However, stratospheric aerosols do affect ozone profile products

Effect on long wavelength (326.4 nm, low ozone absorption):

- Aerosols produce change in zenith-sky measurements that is SZA dependent (Figure 2).
- The effect is caused by the change in the ratio of aerosol and Rayleigh phase function.
- Method for estimation of aerosol information:
  - Does not require absolute calibration of measurements
  - Need correction for ozone absorption (total ozone is known from direct-sun measurements)
- If aerosol optical depth is available from direct-sun measurements then the aerosol single scatter albedo can be derived (requires absolute calibration)
- Stratospheric and tropospheric aerosols produce different SZA effects in the zenith sky measurements (Figure 2c)
- Analysis of SZA dependence in the zenith-sky radiance residuals allows us to distinguish between tropospheric and stratospheric aerosols as long as optical depth is available from direct-sun measurements

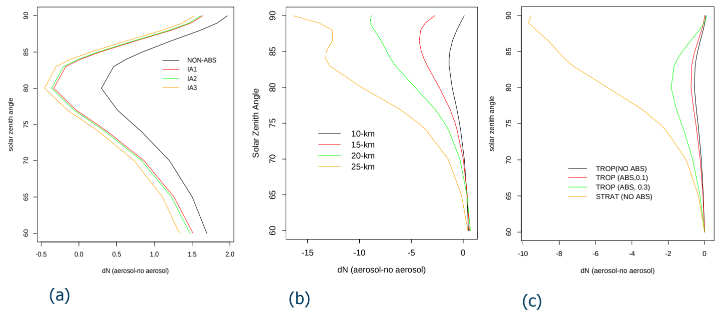

Figure 1. a) Effect of tropospheric aerosols on C-pair Brewer measurements. The change in C-pair N-values relative to clear-sky conditions is shown as a function of solar zenith angle (SZA). The effect of absorption can be assessed by comparing results for non-absorbing and absorbing aerosol cases (defined in legend as NON-ABS and IA respectively).

b) Effect of stratospheric aerosols on C-pair Brewer measurements. The change in C-pair N-values is shown as a function of SZA. The sensitivity of the measurement to the aerosol profile (Gauss, 3-km half-width) is demonstrated by 4 curves. The altitude of maximum aerosol load is provided in legend.

c) Residual effect of aerosols after the normalization procedure (subtraction of 60-deg SZA measurement from measurements at other SZAs), shown as function of SZA. Note that the effect of tropospheric aerosols (both absorbing and non-absorbing) is greatly reduced, but the effect of stratospheric aerosols is large. Thus, only stratospheric aerosols would produce errors in the retrieved ozone profile.

Table 1: Aerosol size distributions

			Radius (microns)		Stand. Dev.		Fraction	Ref. Index	
Type	Sub-type	Model	m1	m2	m1	m2	($x10^{-4}$)	real	imag
Industrial	IA	IA1	0.085	0.641	1.560	2.004	7.00	1.45	0.012
		IA2	0.090	0.676	1.560	2.004	6.84	1.45	0.012
		IA3	0.109	0.804	1.560	2.004	6.95	1.45	0.012

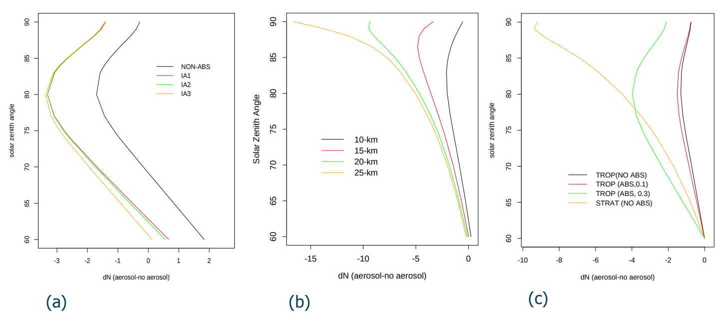

Figure 2. The same as Fig.1, but the effect is shown for the individual 326-nm wavelength measurement (low ozone absorption).

a) The effect of variations in aerosol size distribution is shown in color (IA1, IA2, and IA3 are typical size distributions of absorbing industrial aerosols, see Table 1 for details).

b) Maximum aerosol load altitude information can be determined from residuals at large SZAs.

c) Residual effect of different aerosols on 326-nm measurement after normalization. Normalization removes information regarding aerosol absorption (compare cases for tropospheric aerosols with (TROP, ABS, 0.1) and without (NO ABS) absorption). However, the information about aerosol optical depth is preserved (compare change in N-values at 80-degrees SZA for two cases of absorbing tropospheric aerosols (TROP, ABS) that have 0.1 and 0.3 OD). Stratospheric (STRAT, NO ABS, OD=0.1) and tropospheric (TROP, ABS, OD=0.1) aerosols can be also classified based on distinctive SZA dependences of the aerosol produced N-value residuals.

Next steps:

- Conduct further study to define procedures
- Use more aerosol cases to include variety of microphysical parameters
- Define method to distinguish between tropospheric and stratospheric aerosols
- Include case of clouds
- Apply method to operational data for validation

Conclusions:

- After normalization, the tropospheric aerosol has a small (though non-negligible) effect on the Umkehr curve; stratospheric aerosol has a very large effect
- The Brewer 326-nm channel has excellent information to determine aerosol OD and to separate tropospheric and stratospheric aerosols
- The information obtained from the 326-nm channel can be used to correct the Brewer Umkehr ozone products